

The Laboratory for Human Interaction in the Virtual Environment

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Abstract

The Laboratory for Human Interaction in the Virtual Environment at the Naval Postgraduate School is one of the leading groups for the comprehensive study of humans in the virtual environment. The lab builds on work completed by the NPSNET Research Group to push the edge of human interaction. The HIVE Lab is additionally working towards the acceptance of a Masters program for this work at NPS and is driving the creation of the da Vinci Consortium for the study of humans in the virtual environment.

1.0 Background

The NPSNET Research Group of the Naval Postgraduate School (NPS) has been developing a large-scale, networked virtual environment (VE), NPSNET, for the past six years. The goal of that project has been to research and develop the technology for generating real-time, interactive, networked virtual worlds for the combat simulation arena. NPSNET currently allows each workstation in the DIS virtual environment to be a vehicle (ground, air, seagoing) or an articulated human.[LEN 95][OBY 95][MAC 95][PRA 94][STE 96][ZYD 95]

The Laboratory for Human Interaction in the Virtual Environment (HIVE) has expanded the NPSNET Research Group's work in the area of humans. Its mission is to study the interaction of humans in the virtual environment and foster collaboration among the disparate groups at NPS that are involved in the study of humans. An example of the work being done at the HIVE Lab is the development of an interactive military medic trainer. This work initially focused on a detailed analysis of the user requirements for this system; a study of standard military medic training is presently being completed. The team expects to present what they feel can be accomplished with current simulation technology in the coming months. Prototyping of the desired features will be done throughout 1996 using a variety of existing tools in order to facilitate analysis of the system components and to allow early user testing. Through iterative design a system will be developed at the HIVE Lab that can then be used as a basis for further research at this institution and will be freely-distributable to interested parties.

1.1 Staff

The HIVE Lab has been set up as a multidisciplinary working group at the Naval Postgraduate School to allow work at the lab to leverage off of the skills of many of the departments on campus. Though the lab is presently attached to the Department of Computer Science, work is being completed in conjunction with the Operations Research Department to enhance data gathering and task analysis skills of the members, and to further the development of a user-centered design philosophy.

The people involved with the lab are a mixture of faculty, staff, and students attached to the Department of Computer Science. Despite this, the backgrounds and interests of the HIVE Lab mem-

bers are widely varied. As the lab expands, the Lab will search for people with backgrounds in areas that extend those of our present members. A number of people involved with the NPSNET and HIVE Labs work with the Operations Research Department at NPS, and through whom the Lab is obtaining interested faculty and graduate students for its projects. The teaming of OR and CS, with the later addition of members from the departments of Aeronautics and Astronautics, Mathematics, and Mechanical Engineering, will allow the lab to be a true multidisciplinary group with expertise in numerous areas.

1.2 Educational Role

One of the co-authors of this paper has developed a Masters degree program that specializes in Human-Computer Interaction. This program has been authorized by the Department of Computer Science and the Academic Council at the Naval Postgraduate School, the authorizing academic organization for the school. This degree program has formed the basis for the creation of the Modeling, Virtual Environment, and Simulation (MOVES) curriculum. By the completion of the degree by the co-author, the degree will be obtainable by any personnel coming to the Naval Postgraduate School. The HIVE Lab has been integral in this Masters program being accepted as a degree track. The co-author and others at NPS are already working on expanding the courses that are applicable to the study of humans in the VE: psychology, anthropology, cognitive science, narrative, and ergonomics are just some of the areas being considered. These courses will complement the numerous courses already being presented by the school which cover the implementation and study of the technical issues surrounding virtual worlds.

In the coming years, the MOVES curriculum will allow the HIVE Lab to attract a greater number of Masters and Ph.D. students for research in this field. Also, the additional classes developed for this program may be taken by all students to enhance their understanding of the issues involved in allowing humans to interact with the virtual environment.

2.0 Research Agenda

The Laboratory for Human Interaction in the Virtual Environment is designed to become the focal point for human insertion into simulation systems with DIS as its initial focus.[ZYD 95] The HIVE Lab presents the virtual worlds community with the opportunity to promote the development of a program that focuses on the interdisciplinary work needed to correctly develop virtual environments for human interaction. The HIVE Lab is building upon work completed by the NPSNET Research Group in the areas of visual studies; geometric development, including level-of-detail studies; and network, database, and program optimization for the develop-

ment of the VEs. In addition, the HIVE Lab is performing groundbreaking work in the areas of VE training implementation and analysis; continuing decomposition of problems to be solved in a VE; and the development of user-centered design, heuristic analysis, and other human factors and user-interface design processes as applied to the study of VEs.[ACH 93][BAD 93][LEN 95][OBY 95]

The following sections detail the ways in which the HIVE Lab is creating the ultimate program for studying the interaction of humans in the virtual environment; a discussion of the positioning of the group, the consortium it is involved with, and an outline for the future development of the lab.

2.1 Past and Present

As mentioned above, a number of trainers have presently been built at NPS utilizing the NPSNET environment or for inclusion in the NPSNET system (See photo, Cockayne, Plate 1).[LEN 95][OBY 95] These systems address the need for realistic mission rehearsal and training with a variety of features not available in the real world; arbitrary point-of-view (POV), mission review, remote interaction, unlimited life, and variable passage of time to mention a few examples. Many of these systems push the envelope of virtual environment interface hardware while utilizing NPSNET as the visual simulation environment.

We are presently looking at the application of our skills to the creation of a medical training and simulation system. Our focus is on the creation and study of a medic system; this revolves mainly about the understanding and modeling of combat casualty care.[STP 88] This system is not being positioned as a surgical simulator because the focus for the medic field is combat casualty care. We are including lessons learned in the surgical trainers in the development of our system and feel that we will be able to enhance the knowledge base presently utilized by the medical simulation community.

2.2 da Vinci Consortium

The HIVE Lab is intent on acting as a focal point for the cutting-edge work presently being performed on the issue of human interaction in the VE. This notion, along with the need for continued, constructive conversation on topics in this area, drove the HIVE Lab to create the da Vinci Consortium to bring together military, industry, and academia. The HIVE Lab is presently involved in a number of projects with groups that have become the basis for this consortium.

The Naval Postgraduate School, San Jose State University, and the University of California - Santa Cruz (well-respected universities local to our part of California) are collaborating on the creation of a new structured class focusing on "Implementation of Interfaces for Virtual Reality". This class has attracted support and interest from Stanford University, Princeton University, Interval Research, Sense8 Corporation, and a number of other companies and schools: a members of these groups have expressed interest in this consortium. Additionally, the HIVE Lab has approached other companies doing work in the VR industry and the idea of this consortium has been warmly received.

The HIVE Lab developed a focus for this consortium and gathered support during the previous half year. If all proceeds as planned, the consortium will be functioning fully within the year. As time progresses there is hope for the development of a mailing list, newsletter/journal, and conference all related to human interaction in the VE. This area of research is truly complementary to the areas from which it draws its roots; computer graphics, operations

research, and human-computer interaction. People have begun to understand this and are now willing to develop resources equal to those enjoyed by these and other study groups.

3.0 Research Directions of the Lab

Included below is an outline of the medic study which is one the major projects of the HIVE Lab. Through this study we hope to begin providing the VE community with an initial understanding of the issues surrounding the sense of immersion of a user utilizing networked, full-articulated hands and complementary tools.

3.1 Medic Trainer

Work is now being expanded on immersion of humans into the environment in order to deliver an interactive medic trainer. There is a great deal of interest in defining a standard for human subsystems upon which could be built a generic training simulator.[DUR 95]

3.2 Human Entity Study

A number of our graduate students are working on a more generic way of inserting humans into the virtual world. The problem we are trying to solve has been stated in the following way by one of our researchers.

"A sailor walks from the engine room through the ship to the fantail and promptly falls overboard. The ship follows man overboard casualty actions, and a small boat is launched which recovers the sailor. A helo then hoists the sailor aloft and transports him to the helo carrier for emergency treatment."

- Don Brutzman

The key research problem here is to make each person and platform an independent DIS-based entity. "Ownership" of the man overboard transfers from ship to sea to boat and so forth while the human is always in control of self. Independent control of all entities makes the potential training value enormous.[STE 96]

3.3 NPSNET Human Architecture

The HIVE Lab is working closely with the NPSNET Research Group in developing a robust, extensible human architecture.[NRG 96] This architecture will be implemented in the next generation of NPSNET for use by other parties and to allow the HIVE Lab to study a larger number of aspects of dismounted infantry interaction than can presently be performed.

3.4 Medic Interface Requirement Study

The interaction of the medic in a distributed, virtual environment is at the cutting (bleeding) edge of Human-Computer Interaction (HCI). With much of the software and hardware for virtual environments now adequately developed, the VE community needs to focus on the HCI for these systems. HCI has been one of the main areas of "Virtual Reality" that has not been adequately explored nor developed. The National Research Council has singled the study of numerous aspects of the man-machine interface for continued government funding.[DUR 95] Though much work has been done on drawing the user into the virtual environment, very little of this work has been performed by HCI specialists, psychologists, or anthropologists. We are looking more closely at what the VE presently affords and the requirements for a greater feeling of immersion by the user. We will present our findings in a paper on requirements for human interaction, medic interaction, and related usability topics to the research community.

3.5 Medic Interface Development

Once an understanding of the requirements for a medic in a virtual environment is well underway, the creation of this environment will begin.[STP 88] This VE may not be based on NPSNET in order to keep the variables under study to a minimum. We will develop an interface for the medic that focuses on the use of both of the user's hands, natural movements, medic tools, as well as soldier equipment. Integration with NPSNET is the ultimate goal of all software developed in this project. Features that will be focused on in this development are outlined below.

3.6 Wounding Model Integration

In order to facilitate the interaction of the medic, a high-resolution human body model is needed. Wounding can be developed once the human model is completed. The creation of the model and wounding extensions are not being developed at NPS. We will be presenting our requirements for a wounding model to the community working in this area. We are developing a way to include such a model when it is available. Once this human model is delivered, we will integrate it into the medic environment and begin looking at how the user reacts to this initial model. It is unknown at this time what level of detail or realism is required by the medic in the competent performance of her duties. We will be documenting the changes that we feel will enhance the feeling of immersion and presenting this knowledge to the teams working on the next generation of the models. Through iterative design we hope to be able to help the medical community ascertain the features of the human body model which are crucial for the sense of immersion as well as training.

3.7 Simulation of Humans in VEs

NPSNET presently utilizes a motion library derived from the University of Pennsylvania Jack system for presentation of humans in the VE, but the limitations of the system's use in real-time VEs is forcing the research group to look for better solutions. The NPSNET Research Group is interested in other models that have been developed at other research centers or in-house. As mentioned above, the research group, along with the HIVE Lab, is developing a new human architecture for NPSNET that will allow the system the use of any standard, simulated human system. The HIVE Lab is extending a kinematic human model, developed at NPS by a graduate student, so that it can serve as the model for human simulation models. This model is a high priority for the NPSNET Research Group as it would allow for the delivery of full source code related to the human issue. NPSNET is presently distributed as full source code with the exception of the human models and we hope to remedy this as soon as possible.

3.8 Dynamic Tool Model and Networking

This task centers around allowing the medic to realistically work on an injured soldier while exploiting experience with tools that are normally used in combat casualty care. This work will focus on two areas — a study of common medic tools and the implementation of a tool model in the networked virtual environment.

An analysis of the medic's tools will allow us to specify the common traits that need to be embodied in our tool implementation. This work has already begun in conjunction with the Medic Training School at Ft. Sam Houston, San Antonio, TX, and the Presidio of Monterey Medical Center. A task analysis of standard medic procedures will be developed and applied to the tool model to verify accuracy and usability. The Presidio Medical Center will provide us with a number of trained medics who will be utilized in this study for user testing.[STP 88]

Based upon the specification generated in the above analysis, a generic tool model for a networked virtual environment will be developed. This model will be implemented in the next generation of NPSNET so that multiple medics may operate together at remote sites.

3.9 High-Resolution Human Network Implementation

DIS does not presently support the articulated human as an entity. NPSNET does support Dismounted Infantry at a medium level of resolution; the model does not have articulated hands. Work will be performed at the HIVE Lab to allow for the insertion of a high-resolution human into a networked virtual environment, specifically NPSNET. This task requires that a better understanding of encapsulation of gesture data be researched or developed. The task analysis of medic functions will be integrated with the technological model in order to develop a model that meets the requirements of both systems.[BAD 93][STP 88][WAL 95] Once this has been completed, an efficient method for sending this data to interested parties will be implemented; this work will likely build on multicast studies already being completed for NPSNET and MBone. Development of this network implementation will allow the medic to work with other medic support staff in a collaborative environment over the internet. We feel that the ability to perform this type of work with others will greatly enhance the user's feeling of immersion.

This work will initially be done in a prototyping virtual environment and will be integrated into a later version of NPSNET. The network model which is developed will influence the architecture of the next generation of NPSNET. This work will also be presented to the DIS world with the hope that this model will act as a basis for human integration into a VE.

3.10 High-Resolution Human Hands

Work is required on real-time interaction with entities and objects in the virtual environment utilizing position and gesture input devices. The goal of this task is to facilitate the standard operations of a medic in the virtual environment. As the medic is primarily interested in performing emergency medical procedures on injured soldiers in a field of battle, this work will simulate the complete range of medic's hand motions. Within the prototyping environment we will develop a natural mode of interaction using the input devices.[BAR 95][BUX 86][KAB 94][STU 92][WAL 95]

For the future, integration with NPSNET is a top priority. This work will require a more detailed human hand model; work is being completed at NPS to deliver such a model. Development of the next generation of NPSNET will also facilitate the integration of hands into the virtual environment. Our work on hands and novel input devices is being used as a basis for the pertinent areas of development in this next version of NPSNET.

4.0 Technology Delivery

NPSNET is currently distributed for free with all NPS Developed source code. NPSNET is currently under configuration management for the Department of Defense by the technical staff of the NPSNET Research Group at the Naval Postgraduate School, Monterey, California. The configuration management efforts are carried out via reimbursable contracts with the faculty of the NPSNET Research Group. Over 100 organizations currently utilize NPSNET for the deployment of their VE solutions. The software developed at the HIVE Lab is integrated with the core NPSNET software bed as technology permits.

5.0 Resources

Information on the HIVE Lab can be obtained at:

www-npsnet.cs.nps.navy.mil/npsnet/hive/

Information on the MOVES Curriculum at the Naval Postgraduate School can be obtained at:

www-npsnet.cs.nps.navy.mil/moves/

All papers from the NPSNET Research Group are available via the NPSNET Research Group's web page:

www-npsnet.cs.nps.navy.mil/npsnet/

Information on obtaining the full source code for NPSNET is also available at that location.

Information on the da Vinci Consortium can be found at:

www-npsnet.cs.nps.navy.mil/davinci/

6.0 References

[ACH 93] Achorn, B. & Badler, N.I., "A virtual training environment with simulated agents", Conf. on Intelligent Computer-Aided Training and Virtual Environment Technology, 1993.

[BAD 93] Badler, N.I. & Webber B., "Virtual interactive collaborators for simulation and training", 3rd Conf. on Computer Generated Forces and Behavior Representation, Orlando, FL, March 1993

[BAR 95] Barfield, W. & Furness, T.A. (Eds.), Virtual environments and advanced interface design, Oxford University Press, New York, 1995

[BUX 86] Buxton, W & Mayers, B., "A Study in Two-Handed Input", Proceedings of CHI '86, 1986, 321-326

[DUR 95] Durlach, N.I. & Mavor, A.S. (Eds.), Virtual reality: scientific and technological challenges, National Academy Press, Washington, D.C., 1995

[KAB 94] Kabbash, P., Buxton, W. & Sellen A., "Two-handed input in a compound task" in Proceedings of CHI '94, 1994, 417-423

[LEN 95] Lentz, F.C., Shaffer, A.B., Pratt, D.R., Falby, J.S., Zyda, M.J., "NPSNET: Naval Training Integration", in the Proceedings of the 13th DIS Workshop, 18-22 September, 1995, Orlando, Florida

[MAC 95] Macedonia, M.R., Zyda, M.J., "A Taxonomy for Networked Virtual Environments", in the Proceedings of the 1995 Workshop on Networked Realities, Boston, MA, 26-28 October, 1995

[NRG 96] NPSNET Research Group, "OpenNPSNET Architecture", Unpublished design document, 1996

[OBY 95] O'Byrne, J.E., "Human Interaction within a Virtual Environment for Shipboard Training", Master's Thesis, Naval Postgraduate School, Monterey, California, September, 1995

[PRA 94] Pratt, D.R., Barham, P.T., Locke, J., Zyda, M.J., Eastman, B., Moore, T., Biggers, K., Douglass, R., Jacobsen, S., Hollick, M., Granieri, J., Ko, H., Badler, N.I., "Insertion of an Articulated Human into a Networked Virtual Environment", Proceedings of the 1994 AI, Simulation, and Planning in High Autonomy Systems Conference, University of Florida, Gainesville, 7-9 December, 1994

[STE 96] Stewart, B.C., "Mounting Human Entities to Control and Interact with Networked Ship Entities in a Virtual Environment", Master's Thesis, Naval Postgraduate School, Monterey, California, March 1996

[STP 88] Soldier Training Publication No. 8-91-SM, "Soldier's Manual CMF 91 General Medical Tasks", Critical Tasks for MOSs 42C, 91A, 91B, 91C, 91D, 91F, 91G, 91H, 91J, 91L, 91P, 91Q, 91U, 91V, 91Y, Headquarters, Department of the Army, Washington, D.C., 7 September, 1988

[STU 92] Sturman, D.J., "Whole-hand Input", 1992, Media Arts & Sciences, Massachusetts Institute of Technology, Dissertation

[WAL 95] Waldrop, M., Pratt, S.M., Pratt, D.R., and McGhee, R., Falby, J.S., & Zyda, M. J., "Real-time Upper Body Articulation of Humans in a Networked Interactive Virtual Environment", in The First Workshop on Simulation and Interaction in Virtual Environments (SIVE95), University of Iowa, Iowa City, IA, 13-15 July, 1995 pp. 210-214

[ZYD 95] Zyda, M.J., Pratt, D.R., Pratt, S.M., Barham, P.T., Falby, J.S., "NPSNET-HUMAN: Inserting the Human into the Networked Synthetic Environment", in the Proceedings of the 13th DIS Workshop, 18-22 September, 1995, Orlando, Florida

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